Lat 39.36422 Lon -120.20575

Forest Health Protection
Pacific Southwest Region

Date: April 14, 2006
File Code: 3420

To: District Ranger, Truckee Ranger District, Tahoe National Forest

Subject: Managing Annosus Root Disease in the Alder Creek Project.
(FHP Evaluation # NE06-06)

On November 14, 2005, Forest Health Protection (FHP) personnel examined part of the planned Alder Creek Project on the Truckee Ranger District, Tahoe National Forest. The objectives were to survey for annosus root disease and provide management recommendations regarding stump treatment with SPORAX® to control annosus root disease. Teri Banka (District Planner) accompanied Bill Woodruff (FHP Plant Pathologist). The Alder Creek Project is located along the north side of Alder Creek a little west of Highway 89. The Alder Creek Project area is forested with ponderosa pine, lodgepole pine and white fir, both in the overstory and understory. Some of the overstory trees are large old ponderosa pine and lodgepole pine.

Evidence of annosus root disease was found on white fir in the project area in the form of characteristic decay in the roots of a windthrown white fir caused by *Hetrobasidion annosum* (fir/s-type). Fir or s-type annosus root disease is common in white fir in eastside Sierra Nevada forests. Pine or p-type was not confirmed within the project area. No *H. annosum* fruiting bodies (conks) were found in conifer stumps in the project area. In 1989, p-type *H. annosum* conks were found in ponderosa pine stumps in five areas 3.5 to 9 miles northeast of the Alder Creek Project area (Kliejunas, FPM Report No. 89-16). *H. annosum* spores from these localities could reach the Alder Creek Project area and infect ponderosa pine and lodgepole pine stumps.

Some of the old white fir trees have declining crowns with dead and dying branches and some younger white fir have stunted growth, as indicated by rounded tops and short leader growth. Both of these conditions can result from *H. annosum*. Scattered white fir and lodgepole pine snags in the area may have been weakened by annosus root disease before being killed by beetles. Healthy-appearing young and old white fir trees can be found in

NORTHEASTERN CALIFORNIA SHARED SERVICE AREA
2550 RIVERSIDE DRIVE
SUSANVILLE, CA 96130
530-257-2151

Sheri Lee Smith
Supervisory Entomologist
ssmith@fs.fed.us

Daniel Cluck
Entomologist
dcluck@fs.fed.us

Bill Woodruff
Plant Pathologist
wwoodruff@fs.fed.us

the area, indicating that the disease is probably not present throughout or at least has not yet resulted in above ground symptoms.

Root contacts between conifers in stands within the Alder Creek Project area where fir or pine trees are clumped are a common pathway through which *H. annosum* is transmitted tree-to-tree. In addition *H. annosum* can move long-distances by wind-borne spores produced by the disease's fruiting bodies (or conks) which grow on decaying wood of dead and/or dying white fir and pine trees outside the area. Annosus spores can germinate on and infect freshly created conifer stumps and grow into uninfected roots and eventually spread to adjacent uninfected roots of surrounding trees. In addition, annosus spores can infect live white fir trees through naturally-occurring wounds, fire scars and broken tops. Wounds on pine trees are rarely infected because pitch rapidly seals and protects fresh wounds.

In white fir trees *H. annosum* primarily causes heartrot in the roots and butt, sometimes causing hollow cavities where annosus conks often grow. Also, the fungus is capable of causing heartrot throughout the boles of old true fir trees and directly killing true fir seedlings and small saplings. The cambium and phloem in fir trees are usually not affected by *H. annosum* and continue to function, produce wood and keep the tree alive. However, *H. annosum* in a suppressed white fir tree can eventually infect and decay enough root tissue to structurally weaken the tree and further slow its growth. Fir trees weakened by *H. annosum* are commonly killed by fir engraver beetles, *Scolytus ventralis*, often during prolonged periods of below-average precipitation. Evidence of fir engraver can be found on dead and down fir trees in or around the Alder Creek Project area.

In contrast to fir-annosus, pine-annosus quickly colonizes the cambium of ponderosa and Jeffrey pine trees at the root collar and rapidly kills those trees, often within several years. Lodgepole pine is less susceptable to *H. annosum,* and therefore dies more slowly, yet its stump is capable of being infected by the disease. Before any annosus infected conifer is killed by *H. annosum*, it may be weakened by the disease and thereby predisposed to insect caused mortality. The fir/s-type *H. annosum* and pine/p-type *H. annosum* generally do not cross-infect host types. P-type *H. annosum* is known to infrequently infect s-type hosts saprophytically. S-type and p-type annosus spores have been reported to be present year-round in the atmosphere throughout much of the Sierra Nevada Mountains. The signs of annosus root disease which were found on both pine and white fir in and around the Alder Creek Project area indicate that both s-type and p-type annosus spores occur here. As previously stated, these spores can infect healthy root systems through freshly-cut stumps.

Borate compounds have been successfully used for decades in the United States to prevent *H. annosum* stump infection. Originally, generic granular borax was used to treat freshly-cut conifer stumps to keep *H. annosum* from colonizing the roots. Borax, or sodium tetraborate decahydrate ($Na_2B_4O_7\ 10H_2O$), is a naturally occurring mineral which has been used more than 50 years in household laundry and cleaning, household insect control, hand cleaners and soil amendments for improving plant growth. Boron, a key element in borax, is an essential micronutrient for plant life, however high concentrations can be phytotoxic. Forestry use of borax was supplemented, about two decades ago, with the insecticide TIM-BOR®, disodium octaborate tetrahydrate ($Na_2B_8O_{13}\ 4H_2O$), which

was applied to stumps as a liquid. Even though it is effective in controling annosus root disease, TIM-BOR® can no longer used in California because it is not registered for that application. When it became necessary to register borax to control annosus root disease in foretry applications, Wilbur-Ellis Corp. registered only the granular borax as SPORAX®. Essentially, SPORAX® is the same generic borax used for over two decades in forestry and five decades in household and agricultural products. The difference is that SPORAX® has been registered as an approved pesticide for control of *H. annosum*. Only SPORAX® can be used in California for this purpose. As with all pesticides, when using SPORAX® in forestry, this chemical must be purchased, stored, transported, and applied following all applicable laws and regulations. This should be stated in planning documents and contracts for projects where SPORAX® is used.

Research has demonstrated that borax (both granular and liquid formulations) prevents the establishment and growth of *H. annosum* in cut stumps of conifer tree species not already infected. SPORAX® is the only registered pesticide determined effective and safe for use in forestry to treat freshly-cut conifer stumps by scientists and EPA. Biological agents have been used elsewhere in the world to control annosus root disease, but no biological control has been registered for use in California. Since both s-type and p-type annosus spores occur in the Alder Creek Project area, all freshly-cut conifer stumps 14 inches and larger in diameter should be treated with SPORAX®.

Management Alternatives of Annosus Root Disease in the Alder Creek Project

Annosus root disease is present in white fir (s-type) in the Alder Creek Project area and in ponderosa pine (p-type) within 4 miles. The estimated extent of the disease was not determined but infection history indicates that *H. annosum* stump infections in ponderosa or Jeffrey pine, white fir and lodgepole pine could occur in the project area if freshly-cut stumps are not treated with SPORAX®.

No Action Alternative.

Without forest management, annosus root disease will persist in the true fir trees that are currently infected in the Alder Creek Project area and eventually *H. annosum* could infect uninfected white fir trees through naturally-occurring wounds or root contacts. New annosus infections in ponderosa pine and lodgepole pine will be rare because p-type/pine infection centers almost always originate from freshly created pine stumps. Over-crowded and/or diseased conifers will continue to be killed by bark beetle events, often associated with precipitation deficits. Eventually, sufficient woody material from dead and dying trees will accumulate on the forest floor and in the canopy to provide fuel which could sustain a stand-replacing wildfire in some areas. Scientific tree-ring studies have shown large stand-replacing wildfire events to be one disturbance which historically killed decadent/diseased fir stands and initiated the slow process of growing new stands. This cleansing of dead and diseased trees from the forest would have also occurred on a smaller scale when low intensity surface fires flared up in and killed aggregations of dead and diseased trees where too much fuel had accumulated in and under the tree canopy. These frequent low severity fires could have delayed the establishment of fir seedlings in annosus root disease centers long enough for *H. annosum* and other decay fungi to consume most of the roots and die. Today, in the absence of these cleansing wildfires in the Alder Creek Project area, old white fir trees will continue to decline and newly established healthy fir

trees will continue to age and become infected with *H. annosum* through natural wounds and/or root contacts with infected trees.

Historically, areas cleared of diseased or declining true fir trees by wildfire would have most likely regenerated slowly over many decades. During these decades newly established fir seedlings would slowly grow through a dense post-fire brush layer until they reached open sunlight. Only then would growth accelerate to produce fir trees to replace the fire-killed conifers. In areas where frequent low severity burns occurred, fir tree establishment would have been slow because only a small number of fir seedlings would survive the frequent underburns. During this long period of stand replacement, with few or no surviving mature host trees in the stand/aggregation to prolong the disease, old annosus-infected conifer roots would completely decay, thus eliminating the disease. This is one theory explaining how annosus root disease cycled in natural fir stands/aggregations. Since pine/p-type annosus primarily originates from newly created stumps, pine annosus would not have been common, historically.

It should be noted, that even though annosus root disease kills p-type hosts and slows the growth (by decaying wood) of s-type hosts, *H. annosum* is an effective decay organism which decomposes conifer roots and recycles forest nutrients. *H. annosum* also can create hollows in stumps and roots which are sometimes used by small mammals for shelter. Additionally, forests with advanced decline due to annosus root disease will provide openings in the canopy which are beneficial for some species of wildlife and early-successional plant communities, including ponderosa pine and lodgepole pine. Also, snags and downed logs created by annosus root disease help sustain a wide variety of forest life. For this reason, depending on the management objectives for the Alder Creek Project area, annosus root disease could be considered beneficial or detrimental to those objectives.

Thin Conifers and SPORAX® Treat the Freshly-Cut Stumps Alternative

Past surveys have detected fir/s-type annosus root disease within the Alder Creek Project area and pine/p-type annosus root disease within four miles. Furthermore, eastside conifer stands in the northern Forests in the Sierras (including the Tahoe NF) are reported to have high levels of annosus root disease (Forest Service Handbook R5 Supplement 3409.11). Therefore, treating newly created 14 inch and larger stumps with SPORAX® is recommended to prevent infecting the roots and adjacent conifers with *H. annosum*. Infection with this root disease fungus could result in killing some large old conifers in the project area over several decades.

Thinning over-stocked forest stands removes competing trees which frees soil moisture for use by the remaining trees. Healthy white fir trees are capable of surviving in relatively dense stands except during severe drought periods when the trees are stressed and fir engraver beetles are active. Overstocked fir infected with *H. annosum* will eventually experience chronic stress as the disease progresses. This stress will predispose them to fir engraver mortality, even during relatively moist periods. Annosus-caused stress on infected fir trees may be reduced by removing competing trees to increase the vigor of the residual trees. The infected fir trees will never recover from the disease, but they may be able to grow new wood at a rate which exceeds the progress of the disease, thereby maintaining the structural integrity of the bole and roots. Thinning true fir stands, heavily

impacted by annosus root disease, will probably not significantly improve stand growth, but thinning may increase individual tree growth and vigor; and make the released annosus-infected trees more resilient during extended periods of below-average precipitation. Thinning stands infected with annosus root disease will most likely retain individual fir trees on the site longer than if they were left overstocked.

The above discussion pertaining to annosus in white fir also pertains somewhat to lodgepole pine. These p-type host trees appear not to be as severely impacted as ponderosa and Jeffrey pines. Even though they can become infected, annosus-caused mortality is rarely reported in lodgepole pine in California. Most likely, mortality in *H. annosum* infected lodgepole pine is often attributed to bark beetles because the disease symptoms can be masked by the effects of the beetle attacks..

SPORAX® treatment of freshly-cut stumps where the roots are already infected with *H. annosum* will have no effect on stopping the disease in those roots. Stumps must be treated with SPORAX® before the annosus spores germinate and grow into uninfected stumps and roots. Since true fir and lodgepole pine are not often directly killed by *H. annosum*, and since crown symptoms are subtle or non-existent in infected true fir and lodgepole pine, it is often not possible to know which trees and roots are infected prior to cutting; and thus which stumps would benefit from SPORAX® treatment. Therefore, in managing partially infected true fir stands (or suspected lodgepole pine infections), it is recommended to treat all stumps 14 inches and larger. On the other hand, if most of the trees appear to be already infected with *H. annosum*, as indicated by declining crowns, the presence of conks or windthrown fir showing symptomatic root decay, treating stumps with SPORAX® would be ineffective because the roots are already infected. In infected true fir stands, the stress caused by *H. annosum* can be lessened by reducing tree stocking (increasing tree vigor). Alternatively, the disease can be controlled culturally by removing all the s-type hosts and planting p-type hosts. Once a conifer's roots are infected, *H. annosum* will continue to spread and survive, before and after tree death, as long as healthy sound wood is available within the contiguous root system. In the Alder Creek Project area, most of the ponderosa pine, white fir and lodgepole pine appear healthy indicating that annosus root disease is not widespread. Therefore treating the stumps with SPORAX® would be effective in protecting healthy trees from *H. annosum*. Moreover, treating all conifer stumps (s-type and p-type hosts) greater than 14 inches in diameter with SPORAX® would help protect all the residual trees from *H. annosum*, including the many large conifers growing in the project area.

In studied California eastside pine forests, it has taken about 30 years for annosus root disease to die off in overstory removal units where ponderosa pine roots became infected through stump infections. In these studies, natural pine regeneration near infected ponderosa pine stumps was killed by *H. annosum* about 20 years after the overstory was removed. Approximately 30 years later, a second crop of ponderosa seedlings survived, indicating that most of *H. annosum* in the roots died. Now that the residual understory pine trees in the studied areas have grown into mature pine trees it is very important, during subsequent thinning of these codominant trees, to treat freshly cut stumps with SPORAX® because the roots of the large trees are now extensive and interconnected. After the initial harvest 50+ years ago, only a few small trees near infected stumps were killed by *H. annosum* because tree-to-tree spread through the small juvenile root systems was unsuccessful. The majority of the trees now occupying the stands in these studies were

able to grow to maturity with annosus root disease because the *H. annosum* was unable to survive and spread in the small and unconnected roots of the residual trees. Thinning today's stands of mature overstory pine trees without treating stumps with SPORAX® would most likely result in a different and more significant outcome. After thinning, the evenly distributed large stumps would present an ideal entry court for *H. annosum* into a network of interconnected large roots which would be favorable for the survival and spread of the fungus. Many large residual trees could be killed over the next 50 years as the disease spreads stump-to-tree and then tree-to-tree.

Thinning over-stocked mixed pine-fir stands in Alder Creek Project area which are partially affected by s-type annosus root disease will be more beneficial in increasing the stand vigor than in any heavily infected stands that may be present. This is because some of the white fir in partially affected areas are uninfected and more likely to respond to thinning. In the mixed pine-fir stands infected with s-type *H. annosum*, it is wise to favor the pine as leave trees, and cut the fir, since the pine will not be killed by the s-type annosum. In the partially infected stands in the Alder Creek Project area, it is recommended to treat all the conifer stumps 14 inches and greater in diameter with SPORAX®, even though some of the fir trees will already be infected. It is impossible to know which white fir trees are infected and which are not. (Infected ponderosa/Jeffrey pine will generally show signs while they rapidly decline in health. Lodgepole pine trees may or may not show symptoms before they are killed my bark beetles.) Treating all the large stumps with SPORAX® will help protect any adjacent uninfected trees from becoming infected through root contact. However, as previously mentioned, white fir can become infected through naturally-occurring wounds. Infection by annosus and other decay fungi is also possible through mechanical wounds created near the base of trees during logging. As much as practical, it is always important to protect all leave trees from bole damage to minimize infection by *H. annosum* and other fungi.

It is recommended to SPORAX® treat all the freshly-cut ponderosa/Jeffrey pine and lodgepole pine stumps, 14 inches and larger, where the roots of those stumps contact other pine trees. This is true for all p-type *H. annosum* hosts in the Alder Creek Project area (ie. all pine species). Once a ponderosa or Jeffrey pine tree is infected with p-type annosus, the tree will most likely die within few years, either directly from *H. annosum* or indirectly from bark beetle attack. If stumps are not treated with SPORAX®, mortality in post-thinning residual trees will be delayed by the time it takes for *H. annosum* to grow through the stumps and roots of cut trees to the roots and bole of adjacent trees. This process can take more than a decade, depending on many factors. Residual pine tree mortality could continue until all the infected roots have decayed and *H. annosum* has died, at least 30 years or more for ponderosa pine, depending on how the disease progresses through the stand. Annosus root disease can continue spreading tree-to-tree in a mature pine forest indefinitely, as long as there are uninfected pines connected by root contacts to infected pines.

Treating stumps with SPORAX® is wise, since a stump surface is an ideal pathway to the roots for *H. annosum*; a pathway that is uncommon in nature. Choosing not to treat stumps will probably not totally decimate a conifer stand. As is seen elsewhere where true fir stands are heavily impacted by annosus root disease, trees continue to survive and grow. However, the infected stands grow at a reduced rate, compared to uninfected fir stands and tree failure due to root decay is common. Growth loss is evident by observing annual

height growth differences between healthy and diseased trees. Harvesting healthy fir stands without treating the stumps will introduce annosus root disease to the stand at an increased rate, compared to what would occur naturally. The stand will survive, yet it will begin to decline more rapidly than without annosus root disease. Choosing not to SPORAX® treat 14 inch and larger stumps when thinning an old pine or mixed conifer stand will result in killing some of the large leave trees. The number killed depends on the size and species of the stumps and the distribution of s-type and p-type hosts.

Past experience with harvesting pine in California has shown annosus root disease to be more damaging in partial cuts than in clearcuts. This is because the root disease dies out in a clearcut before the planted trees reach maturity. Losing a few seedlings per acre to annosus root disease during the interim may not significantly impact the future stand. However, in selectively thinned stands of large pine trees, survival of the residual pine trees is much more critical since there are much fewer trees remaining after the thinning. A stand of mature pine could be significantly impacted by annosus root disease after a thinning where the 14 inch and larger pine stumps were not treated with SPORAX®. This is because each large stump is connected to an extensive root system which has a high probability of contacting one or more leave trees, thereby transmitting *H. annosum*.

Thin Conifers Without SPORAX® Treating the Freshly-Cut Stumps Alternative

Past surveys have detected fir/s-type annosus root disease within the Alder Creek Project area and pine/p-type annosus root disease within four miles. Furthermore, eastside conifer stands in the northern Forests in the Sierras (including the Tahoe National Forest) are reported to have high levels of annosus root disease (Forest Service Handbook R5 Supplement 3409.11). Therefore, cutting conifers in the project area without treating the newly created 14 inch and larger stumps with SPORAX® will result in infecting a number of adjacent conifers with *H. annosum.* As discussed in Alternative 2, once infected, the growth of the conifers will be reduced and tree mortality will increase. White fir trees infected with *H. annosum* will suffer growth loss, increased beetle related mortality and increased tree failure resulting from root decay. Ponderosa and Jeffrey pine infected with *H. annosum* will die within a few years of infection. Lodgepole pine with *H. annosum* will live longer, but will die at an accelerated rate compared to uninfected trees. In the long-term, trees infected with *H. annosum* will die or create combustible fuels (eg. dead needles, branches and tops) faster than healthy trees thereby increasing the risk of stand replacing wildfire.

As discussed in Alternative 2, tree mortality following thinning will be delayed by the length of the infection process. Initial mortality could occur in ponderosa/Jeffrey pine as early as a decade after the freshly cut stumps are infected with *H. annosum* to as late as several decades. Once established, *H. annosum* will spread tree-to-tree through interconnected roots of s-type or p-type hosts, causing secondary and later tree mortality many decades after the untreated stumps were first exposed. Some of the large ponderosa pine could be killed directly by *H. annosum* and some of the old lodgepole pine stressed by *H. annosum* could be killed by bark beetles. Some of the young s-type and p-type hosts might die as well. In addition, conifer seedlings established in the future might grow into contact with infected roots and die.

It is impossible to predict the number of stumps that would become infected in the Alder Creek Project area if not treated with SPORAX®. Past studies on the Shasta Trinity and

Modoc National Forests have found between 3% and 17% of untreated 18 to 22 inch ponderosa pine stumps and between 8% and 35% of untreated 22 to 26 inch ponderosa pine stumps supporting active *H. annosum* infection centers decades after the stumps were exposed. Pine stumps smaller than 14 inches did not appear to support active *H. annosum* infection centers.

Again it should be noted, that even though annosus root disease kills p-type hosts and slows the growth (by decaying wood) of s-type hosts, *H. annosum* is an effective decay organism which decomposes conifer roots and recycles forest nutrients. *H. annosum* also can create hollows in stumps and roots which are sometimes used by small mammals for shelter. Additionally, forests with advanced decline due to annosus root disease will provide openings in the canopy which are beneficial for some species of wildlife and early-successional plant communities, including ponderosa pine and lodgepole pine. Also, snags created by annosus root disease help sustain a wide variety of forest life. For this reason, depending on the management objectives for the Alder Creek Project area, annosus root disease could be considered beneficial or detrimental to those objectives.

If you need further assistance, please contact Bill Woodruff at 252-6680. A short biology of annosus root disease and a copy of FSH R5 Supplement 3409.11-94-1 are attached to provide more information on annosus root disease.

/s/ Bill Woodruff

WILLIAM C. WOODRUFF
Plant Pathologist

APPENDIX

Biology of Annosus Root Disease (*Heterobasidion annosum*)

Heterobasidion annosum is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridenta*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, *H. annosus* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from *H. annosus* are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

Occasionally, infections will cross from roots of pine to roots of true fir; however, rarely is the fungus observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, *H. annosus* is commonly found only on true fir and mortality rarely includes both species within an infection center.

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK
R5 SUPPLEMENT 3409.11-94-1
EFFECTIVE 5/17/94
CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of H. annosum have distinct differences in host specificity. To date, all isolates of H. annosum from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but H. annosum is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113º F (45ºC) and mycelium in wood is killed after exposure for one hour at 104º F (40ºC). Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level (40º C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above 40ºC in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace H. annosum. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H annosum. Use the following similar symptoms for correct diagnosis:

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.

b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns

becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.

c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime. They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on

the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers, thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches ***(Note: Revised to 14 inches: Ref. Kliejunas & Woodruff, FHP Report # R04-01)*** or greater in diameter is highly recommended during

chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches ***(also revised to 14 inches)***. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

a. The objectives and management direction for the stand.

b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.

c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand my be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor

existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with H. annosum would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

REFERENCES

Hadfield, J.S., D.J. Goheen, G.M. Filip, C.L. Schmitt, and R.D. Harvey. 1986. Root diseases in Oregon and Washington conifers. USDA Forest Service, Pacific Northwest Region, R6-FPM-250-86. 27 p.

Otrosina, W.J., and F.W. Cobb, Jr. 1989. Biology, ecology, and epidemiology of Heterobasidion annosum. p. 26-33. In: Otrosina, W.J., and R.F. Scharpf, technical coordinators. 1989. Proceedings of the Symposium on Research and Management of Annosus Root Disease (Heterobasidion annosum) in Western North America. April 18-21, 1989; Monterey, CA. USDA Forest Service, General Technical Report PSW-116. 177 p.

Smith, R.S., Jr. 1993. Root Diseases. p. 136-149. In: Scharpf, R.F., technical coordinator. 1993. Diseases of Pacific Coast Conifers. USDA Forest Service, Agricultural Handbook 521. 199 p.

ADDED REFERENCE

Kliejunas, J., and B. Woodruff. 2004. Pine Stump Diameter and Sporax® Treatment in Eastside Pine Type Stands. USDA Forest Service, Pacific Southwest Region, Vallejo CA, Forest Health Protection Report Number R04-01. 7 p.